Management of intelligent spaces and buildings: a distributed and hierarchical model

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Abstract—Three years ago, a private company (DomoCiber) and two departments of two public Universities (Minho and Oporto) initiated a co-operative project : to produce a commercially available system for the management of intelligent spaces and buildings (IS&B). This system would improve the paradigm of IS&B in new trends. The paper describes the main features of the results of this work, which is already present in the market. Namely, we will outline some aspects such as standardisation, compatibility, open systems, friendly using interfaces and a programming language.

KEYWORDS: Intelligent Buildings, Networks, Controllers, Distributed systems, Hierarchical models.

I. GENERAL MODEL FOR INTELLIGENT BUILDINGS

Without complicated considerations on the general model, we could consider IS&B as an auto regulated building under a certain random and dynamic exterior condition and agreeing to objectives defined by several human users.

Three entities can be defined in this model: the outside world (the states or exogenous entities that are relevant to auto regulation - physical world, temperature, humidity, luminosity, intruders, security entities, fire departments), the IS&B (*strictum sensum*) and the user (the entity that can manage the configuration of the IS&B or define the objectives).

Between these entities there must be an intense communication. The IS&B must know the outside world state, must accept orders by the users, must transmit to the user warnings and states.

In present days, buildings have already several communication nets. The first feature of the solution provided by DomoCiber's system is the use and integration of such nets. A graphical model for that global integration, and the 'bridges' between the nets can be seen in fig. 4 (at the end of the text).

II. DOMOCIBER DEVICES

The core of the system lies on what we call DomoCiber Devices (DD) - a set of hardware and software pieces that can communicate through a protocol of messages. According to the messages they receive and send, there are eight types of DDs as shown in table 1.

The messages between DDs obey to a protocol and contain information about Destination, Origin, Date, Time and Message Text.

The operation of message traffic is as follows :

- A DD must send a message to another DD
- DD see in system configuration the physical channels to others DDs and their priorities
- Try to send message with priority order
- If it can't send in all the channels, stores message until it can.

Table I
TYPES OF DDS

BM	Building Manager	• accepts user´s management of system configuration • activates / inactivates user's defined objectives
BC	Buiding Controller	• controls the execution of user's purposes, according to the states and events it receives from EDD, and gives orders to AD to actuate
EDD	Event Detector Device	• read states of building and outside world
AD	Actuator Device	• actuates on devices that can change the outside world
EDD/AD	Event Detector / Actuator Device	• does the functions of EDD and AD devices • can have local intelligence
MD	Monitoring Device	• show actual or ancient state of building
SD	Storage Device	• storage events or states of building
MS	Message Server	• manages communications between devices

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They can be physically supported by:

- Windows DDE
- NetBios Network
- Serial Port
- Parallel Port
- Memory Buffer

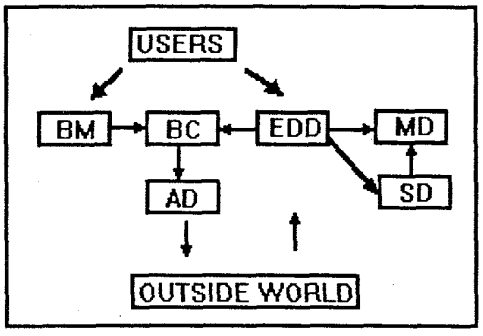

Fig. 1. Messages between DomoCiber Devices.

Generally, the set of messages between DomoCiber Devices follows the scheme presented in figure 1, and are described as:

- BM sends messages to all other devices with alterations to system configuration.
- BM also send messages to BC to activate or inactivate objectives.
- BC send messages to EDD and AD with alteration of configuration in real time
- BC also asks EDD for unconditional state report
- EDD send messages of states and events to BC, MD, SD
- MD and SD send message to EDD to define type of events or states requested

Not to exhaustively describe the whole set of messages available, we present only the messages exchanged from BM to BC :

AddCell *RefCell Type*
DeleteCell *RefCell*
AddRule *RefRule Enabled RuleText*
DeleteRule *RefRule*
ExecuteRule *RefRule*
EnableRule *RefRule*
DisableRule *RefRule*
ExecuteRuleImmediatly *RuleText*

DomoCiber is an open system. New DomoCiber Devices must only communicate with one of the precedent physical channels and obey the rules of messaging. For creation of new devices, Windows OLE Objects and DLL's are available.

For example, a fire security central with RS232 communication could be upgraded to a EDD / AD DomoCiber Device.

III. THE HIERARCHICAL LEVELS

The system provides three levels of intelligence.

The first is accomplished in the EDD / ADs. They can function by itself.

The logical functions they can provide are, however, very low.

They can do what follows :

When an event occurs :

- the relevance of that event may be changed
- the relevance of another event may be changed
- a message may be sent to the AD to produce an action

For example an ADD / ED controls a temperature sensor, a radiator and an acoustic alarm. When an event occurs, (greater then 27°C) this event is no more relevant; another event, (less then 24°C) begins to be relevant, and the heater is activated. If temperature is greater then 50°C then alarm rings. This is the type of logic these ADD / ED can sustain.

The second level is supported by the BC, which can perform very complex logical tasks. The BC needs to communicate to EDDs and ADs in order to 'know' and to 'act'.

Several of these EDDs and ADs may be connected to one BC.

The third level is defined in the BM. It needs the user to define the objectives and methods to reach them. However, it provides the user with a friendly using interface to help him to achieve this goal.

IV. THE BUILDING CONTROLLER (BC)

The BC is a set of cells and rules.

The cells are memories / values that can be updated by the rules and by the states that the EDDs send to the BC.

The rules are as follows :

Cell = Expression
If *Expression* Then *Function*
Function

Function is one of those :

EnableRule(*RefRule*)
DisableRule(*RefRule*)
ExecuteRule(*RefRule*)
SendMessage(*'DD','MessageText'*)

Expression has a rather more complex syntax. ,but it is not far from other languages' expressions, with variables (cells in this case), constants, operators (arithmetic, logical, comparison), and a well-defined hierarchy.

With this structure of cells and rules, a very complex logical reasoning can be achieved.

For example, this could be set (of course in a structured language, not in a discursive one, as follows):

"If the sun shines and the ground is wet, phone grandmother to come see the garden. If she is not at home, keep the grass's humidity between 35 and 55%, but be careful, don't shower the kids."

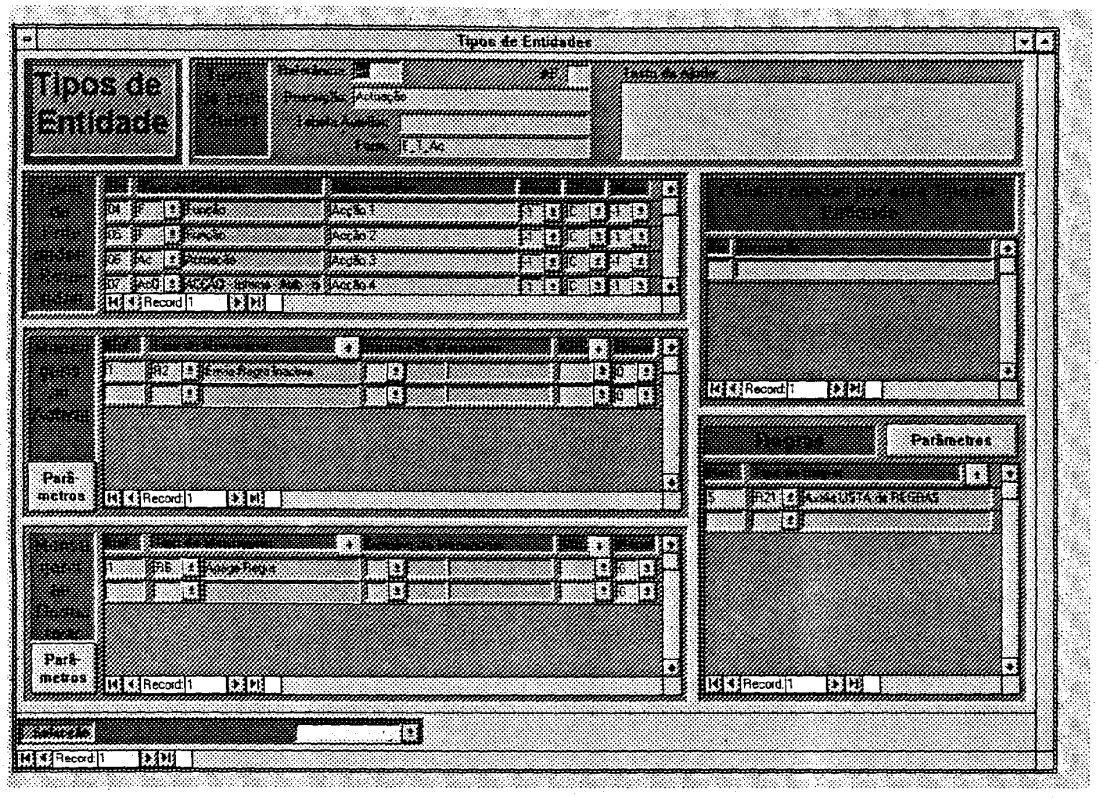

Fig. 2. User entities definition interface module

V. THE BUILDING MANAGER (BM)

The BM is a programming language.

The objects (called Entities) of that language can be defined by the programmer.

What is an Entity? It is something that :

- enables other entities
- disables other entities
- send messages when it's enabled
- send messages when it's disabled
- put cells in the BC
- put rules in the BC

The user is able to define new Entities, as shown in figure 2.

Nevertheless, some entities are ready to use; we present them at Table 2.

Some aspects must be considered here.

As can be seen, complex structures can be created, so that several operations can be set automatically. We refer to these, as examples:

Logical Devices help the user to navigate in this language. They can be defined in a large way, so that they are very versatile. Logical devices as Season of the Year, Medium Temperature of the Building, What John Wants, Yesterday, Is There Somebody Here can be Entities of the language and can be used by the programmer.

An entity can deal automatically with disposability of devices. Suppose the function - Luminosity- wants more light in the room. It can use the lights, and the windows. If we give priority to the windows, it will be tried first. But if the windows are already used by another function (ex: temperature) and this one has higher priority over this device, then, other action must be made (in the example the electric lights). If luminosity has higher priority then windows will be released by temperature, which must find other way to achieve its goals.

An Entity (the Event) permits to accelerate the communications between EDDs and the BC. BC says to the EDD what are the interesting events. So, EDD communicate his state to the BC only when the event occurs, when this state is relevant, avoiding the communication of many non-relevant states.

As in these examples, other more complex structures could be made to improve the performance and ease of use.

Table 2
PRE DEFINED ENTITIES USED WITH BM

Symbol	Name	Rules	Cells	Obs.
F	Function	Set of M and MH		These are the objectives the user wants to be achieved
M	Method	If S Then Ac		
MH	Hierarchical Method	If DL IsNotAvailable Then SendMessage If DL IsAvailable Then Ac If DL WasNotAvailable Then SendMessage DL IsNotAvailable		This Entity permits a F to use alternate methods when the actions it wanted to perform cannot be executed.
S	Situation	Conjunction of States(bellow)		
SD	State - Availability	DL IsAvailable		
SFE	State - Physical Statical	DF Op K SendMessage(NewEvent)		this state creates automatichally relevant events
SFD	State - Physical - Dynamic	DF Op Cell SendMessage(NewEvent) If Cell changes SendMessage(NewEvent)		"
SObj	State - Objectiv	ObjectiveOf DL = Value		
Ac	Action	Set of Actions (bellow)		
Ac_FA	Enable Function	Enable Function		
Ac_FD	Disable_Function	Disable_Function		
Ac_Obj	Defines Objective	Cell = Value		
Ac_AcF	Do Action	SendMessage('AD',DoAction)		
K	Constant			
Op	Operator			
DF	Physical Device		Value Unavailable	Device that reads the outside world
DFAc	Physical Actuator device		Value Unavailable	Device thar acts in the outside world
DL	Logical device	EnableRules	Value Proprietary Function Objective	Set of Logical States (EL)
EL	Logical States	If S then DL = Expression		

VI. THE EVENT DETECTOR / ACTUATOR DEVICES

These DDs are the more numerous. Some are already developed. Many others can be produced, as we have seen.

Presently we use the devices presented in table 3.

A.. UM-NET

UM-Net is a Net developed over RS485 standard. The description of this net goes beyond the scope of this paper.There are 4 boards designed for it.

Table 3
DETECTOR AND ACTUATOR DEVICES

DEVICE	HARDWARE			TYPE	
	Windows	DOS	Specific	EDD	AD
electro-mechanical control		*	boards of UM-Net RS485	*	*
RS485 terminal		*	board of UM-Net	*	*
voice command		*	sound board + voice recognition	*	
voice messages		*	voice modem		*
Infrared command		*	Infrared Decoder / Emitters	*	
clock / alarm		*		*	
Windows actuator / monitor	*			*	*
phone keyboard		*	phone central with RS232		
keyboards / access control		*	keyboards RS232	*	
printer		*	printer		*
telex		*	telex modem	*	*
fax		*	fax modem		*
video messages		*	video board, modulator		*
video recording		*	video tape recorder RS232		*
data messages		*	data modem	*	*

Table 4.
LIST OF BOARDS.

	A	B1	B2	C	D
dimensions (cm)	6*6	6*6	6*6	10*14	10*22
Digital Inputs / Outputs	3I+3O	16I+8O	8I+8O	38 I/O	88 I/O
Analog Inputs	3	0	4	8 (10bits)	16 (8 bits)
Analog Outputs	0	0	0	0	2
RS485	yes	yes	yes	yes	yes
RS232	no	no	no	yes	no
Display LCD 80*2	no	no	no	yes	yes
EPROM	eeprom	in the processor	in the processor	64kb	64kb
RAM	no	256b	256b	64kb	64kb

It constitutes the hardware support for the control of electro-mechanical devices. It's also the support for a RS485 terminal with keyboard and LCD.Other devices are being developed, to communicate with programmable logic controllers and PC boards, with the same purpose - have interface with Digital and Analog Inputs and Outputs. We present the 4 boards used within the UM-NET at table 4.

B. Voice, Data, Fax and Telex Messages

These Devices allow the system to communicate with the users and other entities to send messages, warnings, situations and events. Voice modems are also able to send messages through local phone net.

Drivers for several boards are available.

C. Voice recognition

This EDD allows the users to send simple voice commands to the system *via* a sound board and are decoded by recognition software.

D. Video Messages

This AD creates video images that are send to a video board with TV output, and then modulated and injected in TV net to be distributed through the building.

E. VCR recording

This AD commands a video cassette recorder (NEC PC-VCR) through its RS232 port. It allows the recording of video images when necessary.

F. Keyboards control

This EDD admits several keyboards with RS232 interface to communicate with the system to provide access and security control.

G. Phone Keyboards

This EDD allows the phone keyboards to work as code commands to the system. Needs phone central with RS232 port. Several drivers are available.

H. Windows terminal

This EDD / AD allows the user to work over designs of floors and schemes of functions, allowing the monitoring and actuation over the devices in the building (Fig. 3.)

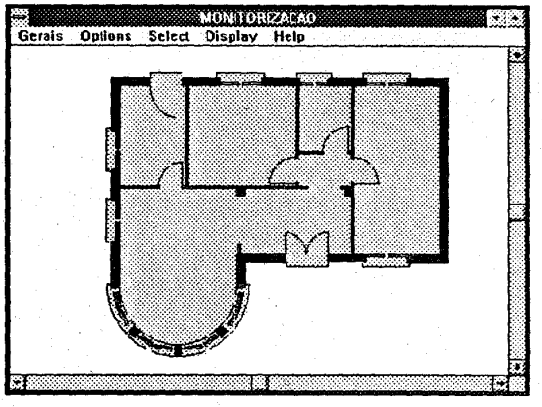

Fig. 3. User works over designs of floors and schemes of functions

REFERENCES

[1] João L. Monteiro, Carlos C. Couto, J. A. Mendes, C. A. Silva, "A Distributed System for Home Environment and Energy Supervision", in *Proceedings of AMSE Conference on Application of Signals, Data, Systems Methodologies to Engineering Problems*, Alexandria, Egypt, December 1992.

[2] João L. Monteiro, J. A. Mendes, C. A. Silva, "A Distributed System for Building Management", *IMEKO 6th International Symposium on Intelligent Instrumentation for Remote and On-site Measurement*, Brussels-Belgium, May 1993.

[3] João L. Monteiro, José A. Mendes, Carlos Silva, Carlos Lima, "A Distributed System to Automate Labor-intensive Industries and Building Supervision", in *Proceedings of IEEE ICIT'94*, 5 to 9 December 1994, Guangzhou - China.

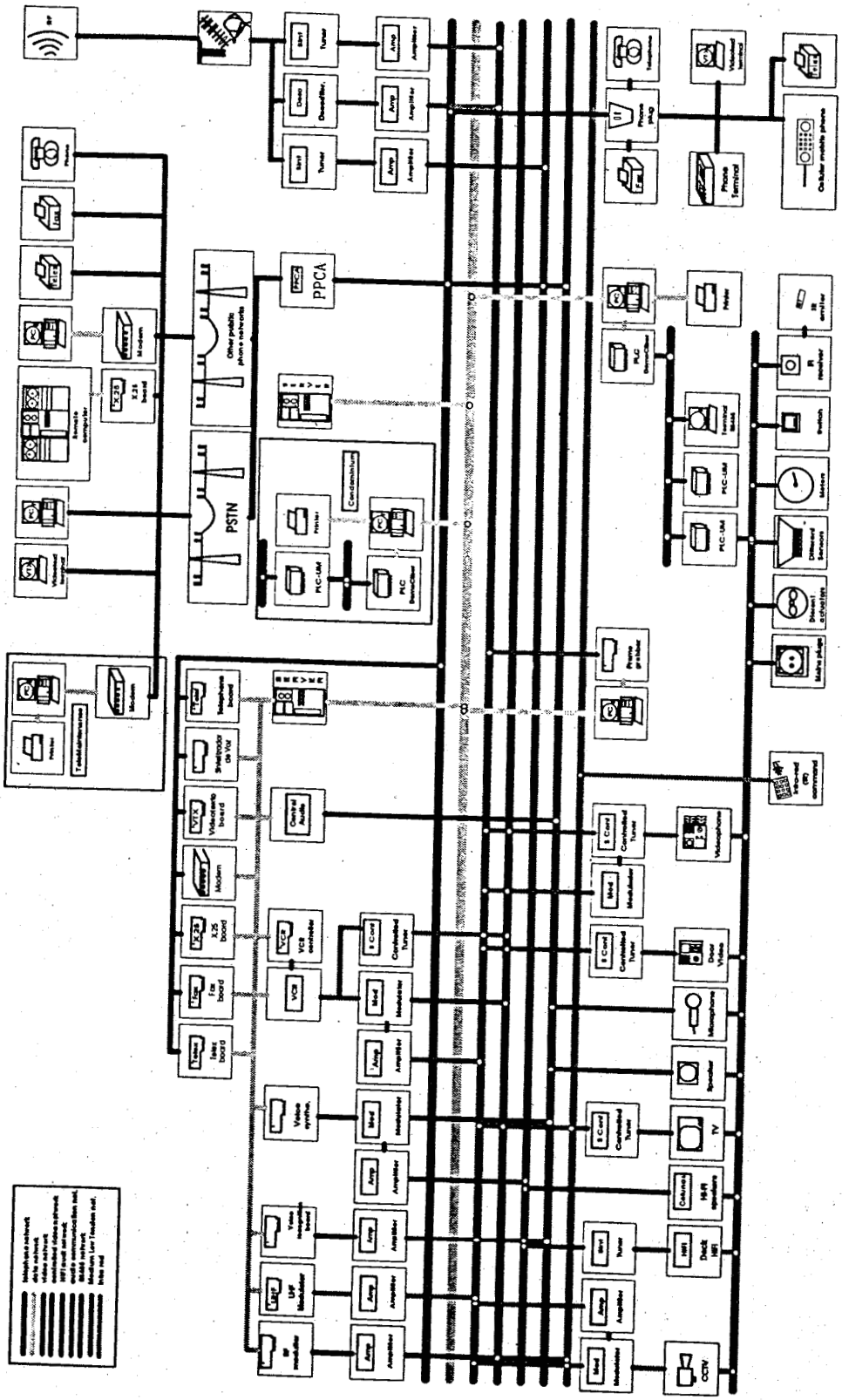

Fig. 4. Graphical model for the global integration, and the 'bridges' between the nets.